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Recognition and Classification of Radioactive Waste using Computer Vision-based Deep Learning Technology

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1. Introduction

The public acceptance of radioactive waste management of Korea Atomic Energy Research Institute (KAERI) has become poor due to the following series problems recently: unauthorized discard, illegal disposal of radioactive materials, input error of radionuclides' concentration within the radioactive waste. To recover the damaged image of KAERI's radioactive management, a prototype study for the radioactive waste recognition & classification using computer vision-based deep learning technology has been being performed, and a classifying system was developed to correctly classify the radioactive at the beginning.

Within the scope of this study, it was to develop an algorithm for the classification of radioactive waste. We aim to increase the efficiency of waste processing facilities and to identify radioactive wastes because the waste separation process is very difficult to separate waste according to the classification criteria with 100% accuracy. The proposed method will be designed not only for environmental benefits but also for saving time and manpower.

In 2012, Alexnet is a type of Convolutional Neural Network (CNN) architecture which was ImageNet Challenge winner, launched a new era in image classification [1,2]. The architecture used in this contest has a simple structure that is not deep. The performance is extremely high. AlexNet's effective performance in the ImageNet competition with a high degree of difficulty has led many researchers to work on CNN structures in the solution of image classification problems.

In this study, it is aimed to develop a deep learning application which detects types of radioactive waste with a computer vision-based system. A computer vision approach to classifying radioactive waste could be an efficient way to process waste (Fig. 1).

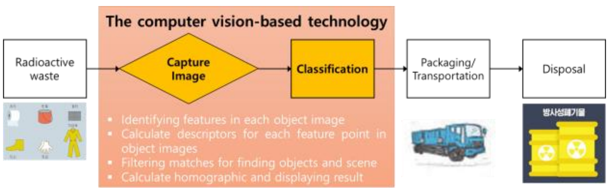

Fig. 1. The overall procedure of radioactive waste management using the computer vision-based deep learning technology

2. Materials and Methods

2.1 Dataset

The main purpose of this study is to separate the process independently of manpower while ensuring accuracy. For this reason, it has been tried to create the infrastructure of an intelligent system by benefiting from deep learning methods. Radioactive waste data were collected for the radioactive waste recognition & classification system, and a database was set up according to the radioactive waste classification criteria. With the collected data, deep learning and inference were performed based on a deep learning neural network. The current database consists of combustible waste in the radioactive waste recognition & classification program, and the radioactive waste can be classified by vinyl, rubber, cotton, paper as a middle-level category. The data set created using a gray background consists of 512x512 size videos. Fig. 2 shows some images belonging to the dataset.

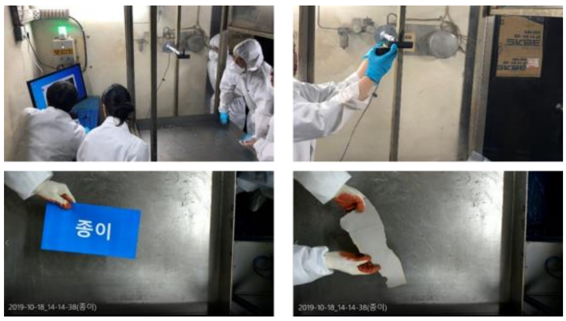

Fig. 2. Process for creating object recognition and classification data

2.2 Deep Learning

Deep learning, called hierarchical learning, aims to analyze the structure of data from simple to complex by using multilayer structures. Deep models can be referred to as neural networks with deep structures. The history of neural networks can date back to 1940s [3], and the original intention was to simulate the human brain system to solve general learning problems in a principled way. In particular, effective features obtained by Convolutional Neural Network make the classification process much easier. This flow, in which complexity increases with the number of layers, facilitates the acquisition of semantic information from structural information.

2.3 Convolutional Neural Network

Convolutional Neural Networks (CNN) is a specialized state of the multilayer neural network and is designed to detect geometric shape in image processing. In a conventional multi-layer neural network, a neuron in the first layer is connected with all neurons in the next layer; the convolutional layer establishes local connections on the output of the previous layer. The fully connected layer performs matrix multiplication [4]. To better understand convolutional neural networks, the first layer on convolutional network identifies the simplest structures contained in the image, for example, through familiar two-dimensional images. Each of many filters in layer is obliged to find one of the edges in a given image. This means that when edge information contained in the image is taken into account, different filters serve for different angles of an edge, or different shapes with other edges. The output of the first layer is feature maps that contain the information of structures that these filters detect. These outputs include information about various edge structures associated with the image. The next evolution layer reveals relationship edges that have been detected on the previous layer on features maps. Each convolution layer analyses correlations of combinatorial structures detected in the previous layer with the image [5].

3. Results

The object of this project is to solve the following two problems by using a deep learning algorithm in the classification of radioactive waste; 1) the wrong re-classification of radioactive waste due to the human error of the worker in the radioactive waste storage, 2) the increased radioactive waste drums due to the improper procedure in the re-classification of radioactive waste. Also, the object of this project is to improve the labor productivity in the detailed re-classification of radioactive waste according to the small size packing policy, and in the inevitable reduction of re-classification work according to the increased self-disposal waste amount, through the deep learning technology.

In this project, the data set used for deep learning structures has a total of 86,084 images with 4 different middle-level category (Table 1). 80% of e images in the data set were used for the training process and remaining part was used for the testing procedure. Also, transfer learning was used to obtain shorter training and test procedures with and higher accuracy.

Table I: Number of training and test dataset by category

Category	**Training data**	**Test data**
Vinyl	27,892	6,923
Rubber	19,514	4,804
Cotton	17,505	4,380
Paper	18,137	4,679
No object	2,124	520
Empty	912	215
Total	86,084	21,521

For a better radioactive waste classification system, the accuracy of classification should be improved, and radioactive waste big data should be set up to include the various radioactive waste data. We have used CNN network. There are six classes in this data set such as vinyl, rubber, cotton, paper, no object and empty. 4 different types in middle-level category of waste images were correctly classified as the highest accuracy as 97.86%. The test result of the radioactive waste classification system trained by deep learning shows almost 98% accuracy (Fig. 3). In the next study, more radioactive waste data should be added to enhance the learning and inference in the deep learning system.

Fig. 3. A result of radioactive waste classification by computer vision-based system

4. Conclusions

The re-classification technology of radioactive waste based on image recognition and deep learning algorithm will play an important role in the development of an automatic recognition & classification of the radioactive waste, and the results of which will be used as an important data in the augmented reality which shows the inside contents of the radioactive waste drums. Also, the re-classification technology will be used in the classification work of self-disposal waste as a useful tool.

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